Human Movement Science 58 (2018) 231–238

Contents lists available at ScienceDirect

Human Movement Science

journal homepage: www.elsevier.com/locate/humov

Full Length Article

Effect of wobble board training on movement strategies to maintain equilibrium on unstable surfaces

Priscila de Brito Silva[a], Natalie Mrachacz-Kersting[a], Anderson Souza Oliveira[b], Uwe Gustav Kersting[a,*]

[a] *Sport Sciences, Department of Health Science and Technology, Aalborg University, Fredrik Bajers Vej 7 D-3, DK-9220 Aalborg, Denmark*
[b] *Department of Mechanical and Manufacturing Engineering, Aalborg University, Fibigerstraede 16, Aalborg East 9220, Denmark*

ARTICLE INFO

Keywords:
Balance
Training
Postural-control
Stability
Counter-movement
Wobble board

ABSTRACT

Standing on unstable surfaces requires more complex motor control mechanisms to sustain balance when compared to firm surfaces. Surface instability enhances the demand to maintain equilibrium and is often used to challenge balance, but little is known about how balance training affects movement strategies to control posture while standing on unstable surfaces. This study aimed at assessing the effects of isolated wobble board (WB) training on movement strategies to maintain balance during single-leg standing on a WB. Twenty healthy men were randomly assigned to either a control or a training group. The training group took part in four weeks of WB training and both groups were tested pre and post the intervention. Electromyography from the supporting lower limb muscles, full-body kinematics and ground reaction forces were recorded during firm surface (FS) and WB single-leg standing. WB training did not affect FS performance ($p = 0.865$), but tripled WB standing time ($p < 0.002$). Moreover, training decreased lower leg muscle activation (29–59%), leg and trunk velocities (30% and 34%, respectively), and supporting limb angular velocity (24–47% across all planes for the ankle, knee and hip joints). Post intervention standing time was significantly correlated with angular velocities at the hip ($r = 0.79$) and knee ($r = -0.83$) for controls, while it correlated significantly with contra-lateral leg ($r \sim 0.70$) and trunk velocity ($r = -0.74$) for trained participants. These results support the assumption that WB training enhances the ability to control counter-rotation mechanisms for balance maintenance on unstable surfaces, which may be a crucial protective factor against sports injuries.

1. Introduction

The term balance typically refers to the ability of sustaining a state of equilibrium by maintaining the vertical projection of the body's center-of-gravity (CoG) within the base of support (Hrysomallis, 2007). Depending on the stability of the support surface distinct sensorial inputs are used to combine different movement strategies and control posture (Horak & Nashner, 1986; Otten, 1999; Riemann, Myers, & Lephart, 2003). While the ankle strategy is effective to sustain balance when standing on a firm surface, higher levels of the sensory system are required to control posture when the base of support is narrowed to a point where there is no consistent proprioceptive input as a spatial reference (Ivanenko, Levik, Talis, & Gurfinkel, 1997). In this case, the ankle strategy alone becomes insufficient to regain balance continuously and an additional counter-rotation mechanism will be employed to prevent

---

[*] Corresponding author.
E-mail addresses: pribsilva@hst.aau.dk (P.d.B. Silva), nm@hst.aau.dk (N. Mrachacz-Kersting), oliveira@m-tech.aau.dk (A.S. Oliveira), uwek@hst.aau.dk (U.G. Kersting).

https://doi.org/10.1016/j.humov.2018.02.006
Received 7 July 2017; Received in revised form 6 February 2018; Accepted 8 February 2018

balance loss (Hof, 2007).

Wobble boards (WB), generally composed of a board with a narrow hemi-spherical base that allows multi-planar movements, are popular devices to induce instability during standing, increasing the demand to sustain balance when standing on the board (Cimadoro, Paizis, Alberti, & Babault, 2013; Mohapatra, Kukkar, & Aruin, 2014; Silva, Oliveira, Mrachacz-Kersting, Laessoe, & Kersting, 2016). Exercises using a WB are typically prescribed for injury prevention and rehabilitation, since the use of such devices reduces lower limb injury occurrence (Emery, Cassidy, Klassen, Rosychuk, & Rowe, 2005; Emery, Rose, McAllister, & Meeuwisse, 2007), especially when there is no chronic ankle instability diagnosed (McKeon & Hertel, 2008). WBs have also been used to evaluate the effect of intervention programs on balance performance, quantified either by standing time on the board or board oscillations (Gioftsidou et al., 2006; Sforza et al., 2003; Sharma, Geovinson, & Singh Sandhu, 2012). To date, no studies have investigated how the movement strategies to control posture are affected by WB balance training. An improved intermuscular coordination and co-activation of muscles, verified during balance performance on unstable supports (Anderson & Behm, 2005) as well as after balance training (Oliveira, Silva, Farina, & Kersting, 2013) may enhance active joint stabilization and help to prevent injury. In order to further describe mechanisms underlying the protective effect against sports injuries induced by balance training it is important to investigate its effect on movement strategies to control posture while standing on unstable surfaces.

The aim of the present investigation was to identify the effect of four weeks of balance training based solely on WB exercises on movement strategies to maintain balance during WB single-leg standing. We hypothesized that WB training will improve balance performance by an improved control of counter-movements of the upper body and the contra-lateral leg. This will be reflected in a decrease of the displacement velocities of the trunk and contra-lateral leg and an increase of muscle activation at the hip when maintaining balance on the WB.

2. Methods

2.1. Participants

Twenty-four healthy men volunteered for the study. Initially, participants filled in the Cumberland Ankle Instability Tool (CAIT) questionnaire (Hiller, Refshauge, Bundy, Herbert, & Kilbreath, 2006) that screens for functional ankle instability. Exclusion criteria included a CAIT-score under 27.5, a history of lower-extremity injury, recent (within the last 6 months) low back injury, vestibular dysfunction or prior experience with systematic balance training. Two participants with a low CAIT-score were excluded and during the training period two other participants dropped out resulting in nine participants as the control group (CAIT-Score 28.2 ± 0.9; age 26 ± 3 years old; BMI = 22.9 ± 1.4) and 11 participants in the training group (CAIT-Score 28.8 ± 1.2; age: 25 ± 2 years old; BMI = 21.9 ± 2.0). Leg dominance was determined through the implementation of three functional tests: ball kick test, step-up test and balance recovery test (Hoffman & Payne, 1995). The participants in this study were recreational practitioners of different team sports and reported to partake in physical activities between 3 and 5 times per week. All participants provided written informed consent before participation and the procedures were approved by the ethical committee of Northern Jutland (N-20120044).

2.2. Experimental design

Initially, all participants took part in a familiarization session that included filling out the questionnaire, the determination of leg dominance and an explanation of the experimental procedures. Experimental sessions with kinetic, kinematic and electromyographic data recordings to assess balance were performed 24 h before the first (PRE) and 24 h after the last training session (POST). Two additional intermediate sessions (INT-1, INT-2) were included to evaluate balance performance, using kinetic and time recordings. Both intermediate sessions were performed after four training sessions, this way INT-1 took place between T4 and T5, while INT-2 took place between T8 and T9. The training group took part in 12 training sessions over four weeks (T1-T12), each 30 min long, conducted three times a week.

2.3. Experimental sessions

Participants were asked to perform 3 × 30 s of single-leg standing on a force platform, which was considered as a firm surface (FS). They were instructed to keep their hands akimbo, stay as still as possible with the contralateral hip and knee at about 30° flexion to ensure the contralateral foot was off the ground. After a three-minute rest, participants were asked to perform a single-leg standing trial on a WB (a 34-cm diameter wooden board with rubber surface, with a half sphere base of 6 cm height and 13 cm diameter – maximal tilt angle = 30°), which was placed on the force platform (Fig. 1). Starting with hands akimbo, they were asked to maintain the board flat (0° tilt) and both the body and the board as still as possible for as long as possible within a 60-s recording period, keeping the contralateral limb away from the ground and the board.

2.4. Data collection

A three-dimensional force platform (AMTI, OR6-5, Watertown, MA) provided ground reaction forces and moments, sampled at 2000 Hz, simultaneously with marker data captured by a motion capture system (8-cameras, Oqus 300, Qualisys, Gothenburg, Sweden) at 250 Hz. Retroreflective ball-shaped markers were placed on the skin overlying the following landmarks bilaterally: heel, first and fifth metatarso-phalangeal joint, lateral malleolus, lateral knee condyle, greater trochanter, anterior and posterior superior